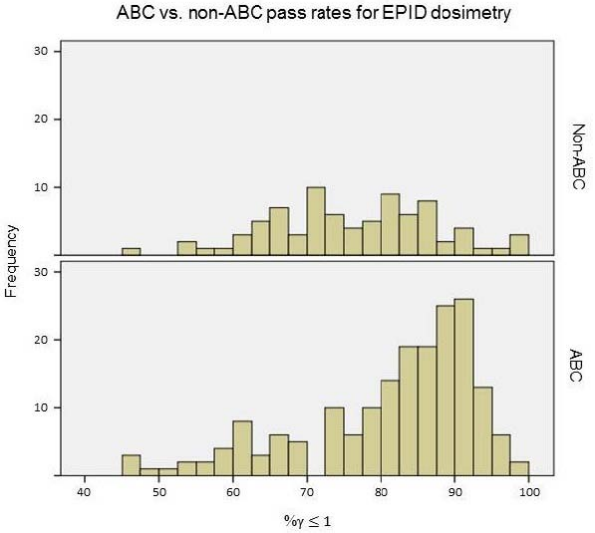
(Vol_dif = Vol_treatment – Vol_CT) could potentially influence the pass rate negatively. Association between Vol_dif and gamma pass rates was analysed by linear regression between the gamma pass rates and Vol_dif squared. In order to adjust at least partially for the residual setup uncertainty, the regression was performed including the fraction number as predictor variable since fields within a fraction are assumed to have the same setup uncertainty.

Results: Difference between pass rates for the ABC and non-ABC group was highly statistically significant ($p<0.001$), with median pass rates of 84.7% and 76.1%, respectively (see figure). However, within the ABC group no significant association was observed between pass rates and deviation of inhaled air relative to the reference from the planning CT. EPID images were used to evaluate patient positioning prior to treatment and only accepted if deviations were less than 5 mm. Thus, it seems likely that the residual positioning uncertainty is the dominant uncertainty relative to the uncertainty in breath-hold volume when using ABC.



Conclusion: Breast cancer patients treated with the use of ABC showed an improved EPID dosimetry pass rate, reflecting an improved accuracy of dose delivery. However, a potential patient selection bias exists since no randomization between groups was performed. No significant association was observed between Vol_dif and pass rate within the ABC group. The ABC system therefore performs as intended and errors in breath-hold volumes are not of concern given the residual setup uncertainties.

PO-0889

Intra-fraction re-setup with Triggered Imaging allows for margin reduction in prostate treatments

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Purpose or Objective: Intra-fraction motion of the prostate during irradiation requires large PTV margins. The recently released imaging application Triggered Imaging (TI, Varian Medical Systems, Palo Alto CA) allows to generate 2D kV images at predefined intervals during irradiation. The application can automatically detect implanted fiducial markers and initiate beam interrupt. Our previous work shows that re-setup was justified for almost half of the beam interrupts based on a 6mm tolerance. This study describes how applying TI and re-setup in the clinical workflow resulted in the reduction of the PTV margin.

Material and Methods: A total of 96 prostate cancer patients with implanted gold seeds were treated on the Truebeam with two RapidArc beams (Software version 2.0, Varian Medical Systems, Palo Alto, CA). For patient setup, the gold seeds are lined up using two orthogonal 2D kV images. After the setup procedure, TI is applied during both beams at an interval of 3 seconds, resulting in 41 images per fraction.In the plannings CT, the center of gravity of each seed is defined as a Marker. During treatment, each seed is automatically detected on each acquired Triggered Image and its center of gravity is marked with a cross. A circular overlay centered at the Marker position is projected on each Triggered Image. The radius of this circle indicates the maximum allowed seed deviation and is referred to as the TI limit. A color coding is used to indicate whether the seed is in or outside the TI limit (Fig 1).If one or more gold seeds exceed the limit for more than 6 seconds the beam is manually paused, while TI continues at the same gantry angle. If the deviation persists for another 6 seconds, the beam is interrupted and re-setup is performed using two orthogonal 2D kV images.For a first group of patients (n=27) TI was used, with the TI limit set to 6mm which corresponds to the PTV margin. For a second group of patients (n=32) the TI limit is set to 5mm, with an unchanged PTV margin of 6mm. For a third group (n=37) the PTV margin was reduced to 5mm, along with a TI limit of 5mm.

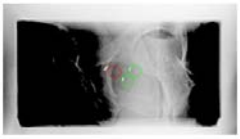

Figure 1. In this figure the auto-detection shows three coloured circles. Green indicates the gold seed is projected within the TI limit, red indicates the gold seed is outside the TI limit.

Results: For the total of 1434 fractions, 134 fractions showed excessive intra-fraction motion of one or more gold seeds leading to 173 beam interruptions and re-setups. Translations applied in re-setup were on average: 3mm, 3mm and 1mm in ventrodorsal, longitudinal and lateral directions, respectively. Overall, the average shift magnitude was 5mm (SD: 2.2mm) with a maximum of 13mm. Shift magnitudes exceeding the PTV margin were considered justified. Table 1 shows that a TI limit that equals the PTV margin leads to about 45% of justified interruptions.

Group (PTV margin/TI limit), n=96	Fractions	Interruptions	Average Shift magnitude (max)	Justified interruptions
Group 1 (6mm/6mm), n=27	305	4.3%	5 (10) mm	46.2%
Group 2 (6mm/5mm), n=32	615	14.0%	5 (12) mm	27.5%
Group 3 (5mm/5mm), n=37	514	14.4%	5 (13) mm	42.5%
Total	1434			

Table 1: Overview of the interrupts and shifts resulting from intra-fraction monitoring with TI.

Conclusion: Triggered Imaging in combination with auto-detection provides a powerful tool to monitor tumor motion during treatment for patients with implanted fiducial markers. We have developed a strategy for intra-fraction re-setup allowing for PTV margin reduction with limited increase in workload.

PO-0890

Homogeneous versus inhomogeneous dose prescription in liver SBRT: effect on delivered CTV-dose

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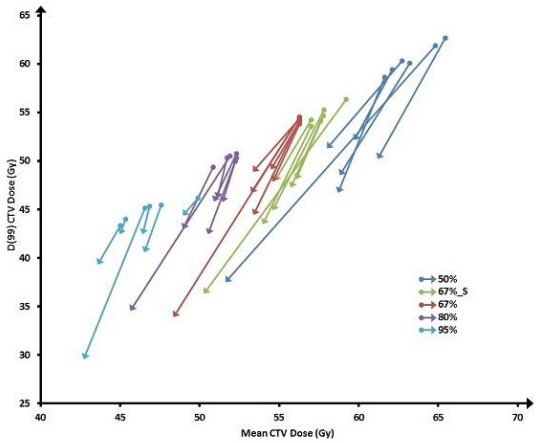
Purpose or Objective: In SBRT it is typical to prescribe a lower dose to an isodose-line encompassing the PTV rim rather than prescribing a uniform PTV dose. This strategy may allow for a higher central tumor dose than achievable by conventional homogenous dose prescription while maintaining an acceptable risk of normal tissue toxicity. However, the tumor dose may deteriorate because of intra-fraction motion. The aim of this study was to determine an optimal dose prescription strategy when explicitly considering the effects of intra-treatment motion in liver SBRT.

Material and Methods: Six patients received liver SBRT in 3 fractions. The PTV was generated from the CTV by adding margins of 5mm (LR,AP) and 10mm (CC). The 3-D motion of an implanted gold marker was monitored throughout each fraction by fluoroscopic kV and MV imaging. Later, five VMAT treatment plans with different PTV dose coverage were

produced for each patient. All plans had a mean CTV dose of 18.75 Gy per fraction (=100% dose) and 95% minimum CTV dose coverage. The PTV was covered by 50%, 67%_S, 67% (our standard), 80%, and 95% of the prescribed dose, respectively. The 67%_S plan was an alternative to the standard 67% plan made with maximum conformity, i.e. as steep as possible dose gradient from 95% to 67% outside the CTV. The 50%, 67%_S, 80%, and 95% plans were renormalized to be isotoxic with the standard 67% plan, i.e. to give the same risk of radiation induced liver disease (RILD) according to the NTCP-model of Dawson *et al*. (Acta Oncol., 2006). For each patient and plan, the dosimetric effects of the observed intrafraction motion were investigated by calculating the delivered dose by an in-house developed method for motion-including dose reconstruction.

Results: The figure shows the CTV mean dose and D99 for each plan type and each patient as planned (start of each arrow) and as delivered with the known tumor motion (end of each arrow). The mean values over all patients are presented in Table 1. The planned CTV dose decreased markedly from 63.3Gy to 47.0Gy (average mean dose) and from 60.5Gy to 44.9Gy (average D99) as the prescription level to the PTV rim was increased from 50% to 95%. Although intrafraction motion reduced this CTV dose difference the CTV dose of plans with high PTV prescription levels remained inferior to isotoxic plans with low PTV prescription levels even when motion was included in the dose calculations, see Table 1. The absolute dose delivered to the liver was almost unaffected by intrafraction motion as seen in Table 1.

Figure 1



Mean dose (horizontal axis) and D99 (vertical axis) for CTV for each plan type for each patient as planned (start of each arrow) and as delivered with the known tumor motion (end of each arrow). Each color represent a plan type.

Conclusion: The dose level at the PTV rim has a large effect on the risk of RILD. Using a low dose at the PTV rim, where the probability of CTV presence during treatment was low, allowed for higher CTV dose for iso-toxic conditions in 50% and 67%_S plans. Although these plans were less robust to intra-fraction motion, their CTV dose remained superior to the 80% and 95% plans when motion effects were included.

Table 1

PTV prescription dose	Planned mean CTV dose (Gy)	Delivered mean CTV dose (Gy)	Planned mean CTV D_{99} dose (Gy)	Delivered mean CTV D_{99} dose (Gy)	Planned mean liver dose (Gy)	Delivered mean liver dose (Gy)
50%	63.3	58.0	60.5	47.8	10.91	10.53
67%_S	57.7	54.2	54.7	44.7	11.03	10.80
67%	56.3	52.9	54.3	45.5	10.97	10.66
80%	52.0	49.7	50.2	43.0	11.05	10.72
95%	47.0	45.5	44.9	39.8	11.13	10.93

PO-0891

Clinical implementation and experience with real-time anatomy tracking and gating during MR-IGRT

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Purpose or Objective: To describe the commissioning process and initial experience using real-anatomy, real-time tracking and gating with MRI-guided radiation therapy.

Material and Methods: An MR-IGRT system was commissioned to enable real-time anatomy tracking and gating. The imaging rate is 4 frames per second; the radiation shuts off when the anatomy of interest is automatically detected outside a pre-defined treatment region. The specific commissioning tests were driven by the goal of compensating for the inherent system latency such that there would not be an increase in treatment margins (i.e., GTV to PTV expansion). Dosimetric and geometric accuracy was evaluated by using both a commercial and an in-house motion phantoms with film and ionization chamber dosimetry. Clinical procedures were developed to maintain the established accuracy during actual patient treatments.

Results: Since initial clinical implementation, 51 patients have been treated using the gating and tracking capability of the MR-IGRT system (out of a total of 193). Based on system characteristics established during commissioning tests, the standard-of-care GTV to PTV expansion was maintained (e.g., 5 mm for abdominal tumors). Dosimetric accuracy was established via ionization chamber measurements that showed a 1.28%±1.7% average difference when comparing gated (with motion) vs. non-gated (without motion) delivery for typical IMRT and open field plans. Spatial accuracy was established via film dosimetric measurements and spatial integrity measurements to be on the order of 2 mm. This level of accuracy is maintained during patient delivery by using the following procedure: setting up to an exhale breath-hold position and using a gating boundary around the region of interest that's 2 mm less than the PTV of interest (e.g., 3 mm expansion of the GTV if a 5-mm expansion to PTV). Depending on the location of the tumor (or other anatomy of interest), duty cycles so far have ranged from about 50% (especially for tumors close to diaphragm) to about 80% (for pancreatic lesions and other abdominal sites excluding liver). Examples are shown in figure below.